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TRANSFER OF OPTICAL ELEMENT PATTERNS ON A SAME SIDE OF A SUBSTRATE ALREADY HAVING A FEATURE THEREON

5 Cross-Reference to Related Applications:

[0001] The present application claims priority under 35 U.S.C. §119(e) to U.S. Provisional Application Serial No. 60/330,504 entitled "Transfer of Optical Element Patterns on a Same Side of a Substrate Already Having a Feature Thereon" filed October 23, 2001, the entire contents of which are hereby incorporated by reference for all purposes.

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Field of the Invention

[0002] The present invention is directed to formation of optical elements etched into a same side of a substrate having a feature thereon, more particularly using patterning, masking and/or reflow techniques.

BACKGROUND OF THE INVENTION

[0003] Fabrication of both refractive and diffractive optical elements on the same side of a wafer is desirable for numerous applications. However, known wafer level creation techniques do not allow for high fidelity patterning of both refractive and diffractive optical elements on the same side of the wafer.

[0004] For example, if the diffractive optical element is created first, the creation of the refractive optical element will degrade the fidelity of the diffractive optical element. This degradation is due to the etching of the diffractive optical element further into the substrate that occurs during the etching of the refractive optical element.

25 [0005] If the refractive optical element is created first, then the high fidelity diffractive optical elements are severely degraded. Also, the topology of the refractive optical element will not allow a high quality thin photoresist layer to be spun onto the substrate. Such a high quality, i.e., uniform, thin photoresist layer is also needed to insure the creation of high fidelity diffractive optical elements. One possible solution is the use of spray coating and projection patterning, but
30 this is not as practical as spinning the photoresist.

[0006] Thus, current lithographic techniques do not permit high fidelity patterning of both refractive and diffractive optical elements when both are to be provided on the same side of the wafer.

[0007] More generally, the above problem arises when a pattern is to be etched into a same surface already containing features which would be affected by the etch process. The larger, i.e., deeper, the feature to be etched, the more likely the etch process will effect the other features already present.

SUMMARY OF THE INVENTION

[0008] The present invention is therefore directed to providing a method of forming an optical element pattern to be etched on a surface having features already thereon, and the structures formed thereby, which substantially overcomes at least one of the above disadvantages.

[0009] It is an object of the present invention to create both refractive and diffractive optical elements in the same side of the substrate.

[00010] It is another object of the present invention to preserve features, e.g., alignment features, metallization features, active optical elements, passive optical elements, already on a surface while etching an optical element into the surface.

[00011] These and other objects of the present invention will become more readily apparent from the detailed description given hereinafter. However, it should be understood that the detailed description and specific examples, while indicating the preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

[00012] The foregoing and other objects, aspects and advantages will be described with reference to the drawings, in which:

[00013] Figure 1 is a flow chart of a general overview of the present invention;

[00014] Figures 2A-2H illustrate the process for forming a diffractive optical element and a refractive optical element on a same surface according to an embodiment of the present invention;

[00015] Figure 3 illustrates a manner of protecting features on a substrate prior to transfer of a pattern into the substrate in accordance with the present invention;

[00016] Figure 4A-4C illustrate different manners of protecting features on a substrate prior to transfer of a pattern into the substrate in accordance with the present invention; and

[00017] Figure 5A-5C illustrate different manners of protecting features on a substrate prior to transfer of a pattern into the substrate in accordance with the present invention;

DETAILED DESCRIPTION

[00018] In the following description, for purposes of explanation and not limitation, specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be apparent to one skilled in the art that the present invention may be practiced in other embodiments that depart from these specific details. In other instances, detailed descriptions of well-known devices and methods are omitted so as not to obscure the description of the present invention with unnecessary details. As used herein, the term "wafer" is to mean any substrate on which a plurality of components are formed which are to be separated to some degree, either individually or as arrays, prior to final use.

[00019] The method for forming an optical element on a surface already having features thereon is shown in the flow chart of Figure 1. Generally, a pattern for forming an optical element is created in a known manner on a surface already having features thereon in step 10. These features may be any structure to be preserved either for functioning in the finished system or for use in further processing, e.g., alignment features. The pattern may be formed in any variety of manners, e.g., using a binary mask, a gray scale mask, stamping, ink jet printing, direct writing. It is then determined in step 12 whether the etching of the pattern would effect the features on the surface. As used herein, etching is to mean any manner of transferring the pattern into the substrate, e.g., plasma etching, dry etching, ion milling, wet etching. If not, for

example, if the height of the pattern to be transferred to the surface is very small, e.g., at least an order of magnitude less, compared with that of the features on the surface, or otherwise does not adversely effect the features, then the flow proceeds directly to the etch 16. More typically, the etch will adversely effect the features, and the features that will be effected are protected in step 14, and then the etch is performed in step 16. After the etch at step 16 is completed, it is determined whether the protection provided in step 14 still remains on the features at step 18. If not, the creation is complete. If protection remains, this protection is removed at step 19, before completion. It is noted that step 10 and step 14 may be performed simultaneously or their order may be reversed. Further, some of the patterning and protecting in steps 10 and 14 may be performed within these steps.

[00020] A specific example of the method is shown in Figure 2A-2H. It is noted that the size of the substrate and the relative size of the diffractives in these figures are only increased to show the additional detail, not due to any of the processes. A blank substrate 20 is shown in Figure 2A. The blank substrate 20 is patterned in any conventional manner to form a diffractive optical element 22 thereon, as shown in Figure 2B. A protective layer is then provided over the diffractive optical element 22. This protective layer should be resistant to the etching to be performed in transferring the refractive structure into the substrate 20. The protective layer should also be able to be removed by a process that does not affect the substrate material.

[00021] In the specific example shown here, a lift-off photoresist layer 24 is patterned to be on the non-diffractive optical element portion of the substrate 20, as shown in Figure 2C. A resistant material 26 is then provided over the substrate 20, as shown in Figure 2D. The photoresist 24 is then lifted off the non-diffractive optical element portion of the substrate 20, taking the unneeded portion of the resistant material 26 with it. A resultant protective layer 28 covering the diffractive optical element 22 is shown in Figure 2E. Other manners of patterning the resistant material 26, such as using a mask, may also be employed to form the protective layer 28.

[00022] Refractive structures 27 which are to be transferred into the substrate 20 are then formed on the substrate 20 as shown in Figure 2F. These refractive structures 27 may be formed in conventional manners, e.g., patterning photoresist and reflowing the photoresist, using gray scale masks, stamping or direct write. The refractive structures 27 are then transferred into the substrate 20, using a process which may not completely remove the protective layer 28, to form

the refractive optical elements 29 as shown in Figure 2G. Finally, the protective layer 28 is removed, resulting in refractive and diffractive optical elements being formed on the same side of the substrate 20.

[00023] The protection of the features already present on the surface at step 14 may be realized in a number of manners, depending upon the pattern to be etched, the etching to be performed, and the features to be protected. For example, if the feature is below or a flat layer on the surface to be etched, a protective material that is resistant to the etch process, but may be removed from the surface without affecting the underlying structure, may be bonded over the features to be protected. In the example shown in Figure 3, a substrate 30 has a diffractive structure 32 therein and a patterned layer 34, e.g., a metal, an anti-reflection coating, a thin film filter, a dielectric layer, a dichroic layer, which is to remain on the surface of the substrate. It is noted that metal may serve an optical function, e.g., an aperture stop, a reflector, and/or an electrical function, e.g., input, output or contact. These features 32, 34 are covered by protective portions 36. This may be realized using a die bonder for individual protective portions or may be realized using a wafer of the protective material with holes therethrough to permit the etching of a pattern for a refractive optical element 38. Alignment tolerances may be realized by oversizing the protective portions. The pattern for a refractive optical element 38 is formed on the substrate, e.g., before the protective portions are provided. One possible material for the protective portions is CaF_2 , which is resistant to fluorine and oxygen, which are commonly used in etching. CaF_2 may be wet etched in ammonium fluoride, which does not damage the underlying substrate, when the substrate is, for example, fused silica or silicon.

[00024] Alternatively, the protection may be provided by patterning a protective material, e.g., photoresist, over the features. This protective layer may be the same photoresist layer to be used in the formation of the optical element, as shown in Figures 4A and 4B. In Figure 4A, a photoresist layer 44 is provided, e.g., screen printed, sprayed, spin coated, or plated, over a refractive optical element 42 on a substrate 40. This photoresist layer 44 is then patterned and etched to form a diffractive optical element. The refractive element 42 is protected during etch by the photoresist layer 44. In Figure 4B, a photoresist layer 46 used to form a refractive optical element is also patterned to remain over the feature 45, here a diffractive optical element, to form a protective photoresist 48. The photoresist pattern 46 is then reflowed to form the lens. The protective photoresist 48 over the feature 45 is also reflowed. Then, the protective photoresist 48

on the feature 45 is etched away as the refractive optical pattern is etched into the substrate 40. Any remaining protective portion may be removed, e.g., by chemical etching.

[00025] However, when the protective photoresist 48 covering the feature 45 is larger, i.e., wider, than the pattern 46 for the refractive optical element while having the same thickness, reflow may result in a lower profile for the protective photoresist 48 over the feature 45 than that for the refractive optical element 46. Then, when etched, the protective photoresist 48 over the feature 45 is removed before the etch of the refractive optical element is complete. Thus, the feature 45 may still be damaged during the transfer. One solution to this problem would be to use a gray scale mask or other technique to leave a thicker photoresist over the feature, so that after reflow, sufficient height remains that the feature is protected during etch. However, using a reflowed protective photoresist also can result in undesired etching around the outer regions of the protective photoresist.

[00026] A solution to this is shown in Figure 4C, in which a protective photoresist 48 and a refractive photoresist are provided and patterned in either order on the substrate 40. Here, the protective photoresist 48 is a photoresist which does not reflow under the same conditions as the refractive photoresist 46. So, when the substrate 40 is subjected to reflow, only the refractive photoresist 46 reflows. The refractive photoresist 46 and the protective photoresist 48 may have the same etch rate, so most of the protective photoresist 48 may have been removed after the etch of the refractive photoresist 46 is complete. Any subsequent complete removal of the protective photoresist may be realized. Alternatively, the refractive pattern could be formed using techniques that do not require reflow, e.g., gray scale masks, stamping, to eliminate the attendant problems of a reflowed protective photoresist.

[00027] Another solution to this problem is shown in Figure 5A, in which further photoresist 58 is provided over reflowed protective photoresist 54 covering the feature 55 on the substrate 50. The refractive photoresist pattern 56 may be sited, or otherwise stabilized, to allow for the additional photoresist 58 to be patterned without affecting the refractive pattern 56.

[00028] Another solution is shown in Figure 5B, in which a protective photoresist layer 58 is patterned to cover a feature 55 on a substrate 50, and then another photoresist layer 54 in which the refractive pattern is to be formed is provided over this layer, e.g., by spinning, and again patterned to remain over the first protective layer 58 and to serve as the refractive pattern 56. After the refractive pattern 56 is reflowed, sufficient protection remains over the feature 55

to protect it during etch. The first protective photoresist may be the same photoresist, may be a photoresist which is more resistant to the etch than the photoresist, or may be less resistant to the etch than the refractive photoresist 56. If the protective photoresist layer 58 is less or equally resistant to the etch, sufficient height of the protective photoresist 58 would need to be provided.

- 5 It is noted that providing a thicker protective layer than the refractive pattern may distort the transfer of the refractive photoresist, due to loading during etching. Further, if the photoresists are different, once the photoresist layer 54 over the feature 55 is etched away, the etch selectivity shifts dramatically, effecting the transfer of the refractive element 56.

[00029] Yet another solution is shown in Figure 5C, where a protective photoresist 58 is
10 provided over a feature 55 on the substrate 50 after the photoresist 56 for the refractive element has been patterned, reflowed, and stabilized, if necessary. Again, the protective photoresist 58 may be the same photoresist, may be a photoresist which is more resistant to the etch than the photoresist, or may be less or equally resistant to the etch than the refractive photoresist layer 56. If the protective photoresist layer 58 is less resistant to the etch, sufficient height of the
15 protective photoresist 58 would need to be provided to insure protection of the feature 55.

[00030] At least one of the above steps in the process, e.g., the formation of the pattern, the provision of protection, and the transfer of the pattern, is performed on a wafer level. The wafer may then be diced to form individual systems.

[00031] It will be obvious that the invention may be varied in a plurality of ways. Such
20 variations are not to be regarded as a departure from the scope of the invention. All such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the present invention.